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The sspm R package: spatial surplus production models for the management of northern shrimp fisheries

Valentin Lucet[*1] **and Eric Pedersen**[†1]

1 Concordia University, Montreal, Quebec, CA

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Software

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Abstract

Productivity models such as Surplus Production Models (SPMs) models can be used to inform stock management of fisheries. However, those models often share three main flaws: (1) they are usually not spatially explicit, (2) fail to incorporate ecosystem predictors and therefore are ill-suited to ecosystem-based management of stocks, and (3) their deployment is often limited by code availability, quality and accessibility. To fill this gap, we developed a lag-1 autoregressive SSPM based on Generalized Additive Models (GAMs), broadly applicable to spatially-structured populations, and bundled into an R package. We applied this model to one of the most economically important invertebrate populations in Canadian waters, Northern Shrimp (Pandalus borealis) in the Newfoundland and Labrador Shelves. This stock currently lacks a population model to predict how fishing pressure and changing environmental conditions may affect future shrimp abundance in the region. Our model incorporates relevant ecosystem predictors for this stock, such as Atlantic Cod (Gadus morhua) density, alternate predator density, temperature, and stock biomass. In addition, the model is deployed through the R package sspm, a flexible framework aimed at making SSPMs easier to apply to spatially structured populations. The package allows for a repeatable and open workflow and improves the accessibility of SSPMs.

Summary

TBD

Statement of need

1. The Northern Shrimp stock in the Newfoundland and Labrador Shelves currently lacks a population model
2. Current SPM models are rarely spatially explicit and isually cannot account for relevent ecosystem drivers
3. Fisheries managers lack user-friendly, flexible tools to implement and apply Spatial SPMs

Introduction

Population modelling is an exercise of interest within environmental sciences and adjacent fields. From early models that addressed simple dynamics such as exponential growth and density dependence, modern models are now ackowledging the non-stationary nature of wild populations. In addition, population models applied to resource management, such as fisheries

*co-first author
†co-first author

models, are incresaingly concerned with how stocks varies accross time and space. Resource managers are becoming more and more interested in how ecosystem factors such as predator abundance and the abiotic varaibles impact the spatial structure of mechanisms like productivity and density dependence. Althought the non-statitionnaity of a wide range of populations has been demonstrated and established, and despite the push for more "ecosystem based management" methods in fisheries management, efforts to include spatial dynamics in fisheries models are rare.

One family of population models that rarely account for spatial structure is the family of surplus production models (SPMs).

$$B_{t+1} = g(b_t) * e^{\epsilon}$$

Population models in fisheries science usually fall under two categories: process-based models and statistical models. Process based models often rely on differential equations and are based on replicating the underlying processes (predation, recruitment, dispersal) behind popupaltion dynamics. Statistical models, on the other hand, rely on fitting a model to data using distributionnal assumptions, and present the advantage of naturally measuring uncertainty around predictions. This is useful in a management context where uncertainty around decision-making is an important information to have on hand.

In this paper...

We apply...

We make it flexible and user friendly...

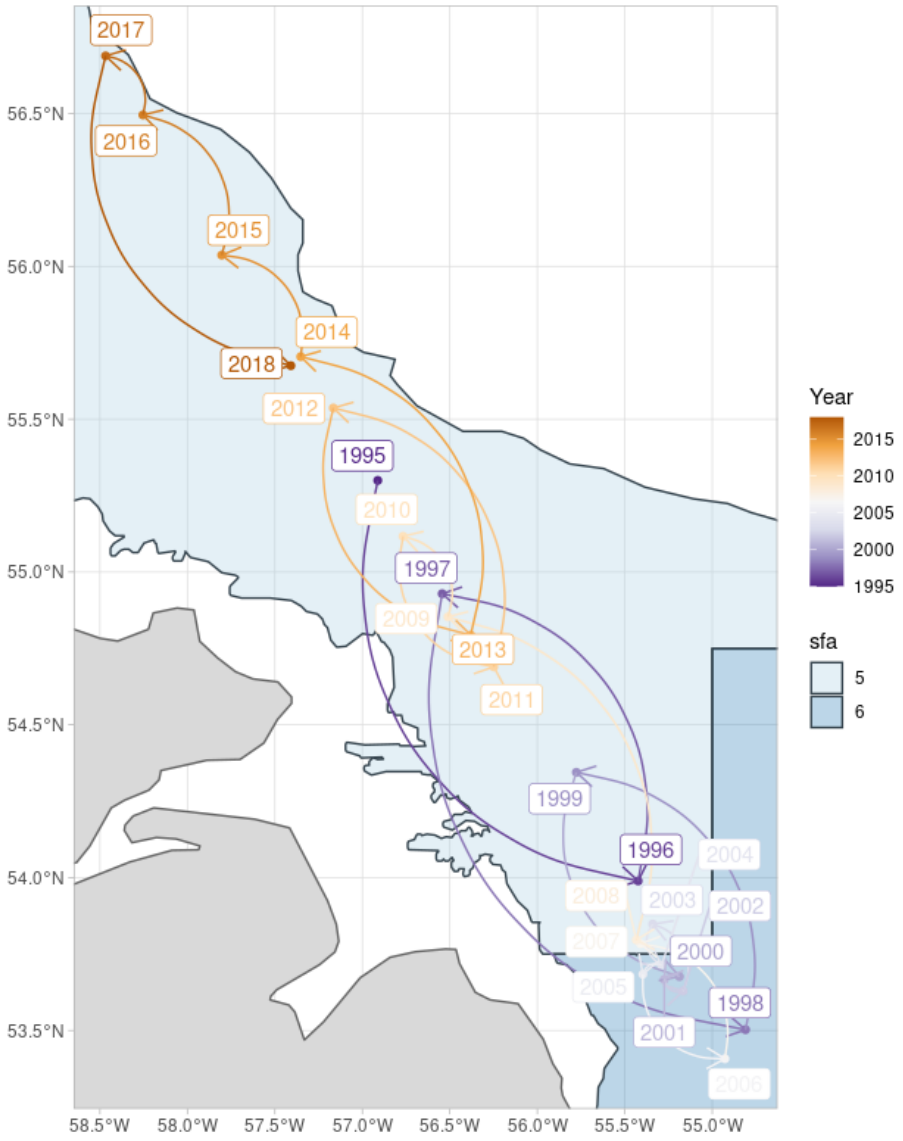


Figure 1: Northward shift of weighted centroid of biomass trawled.

Model

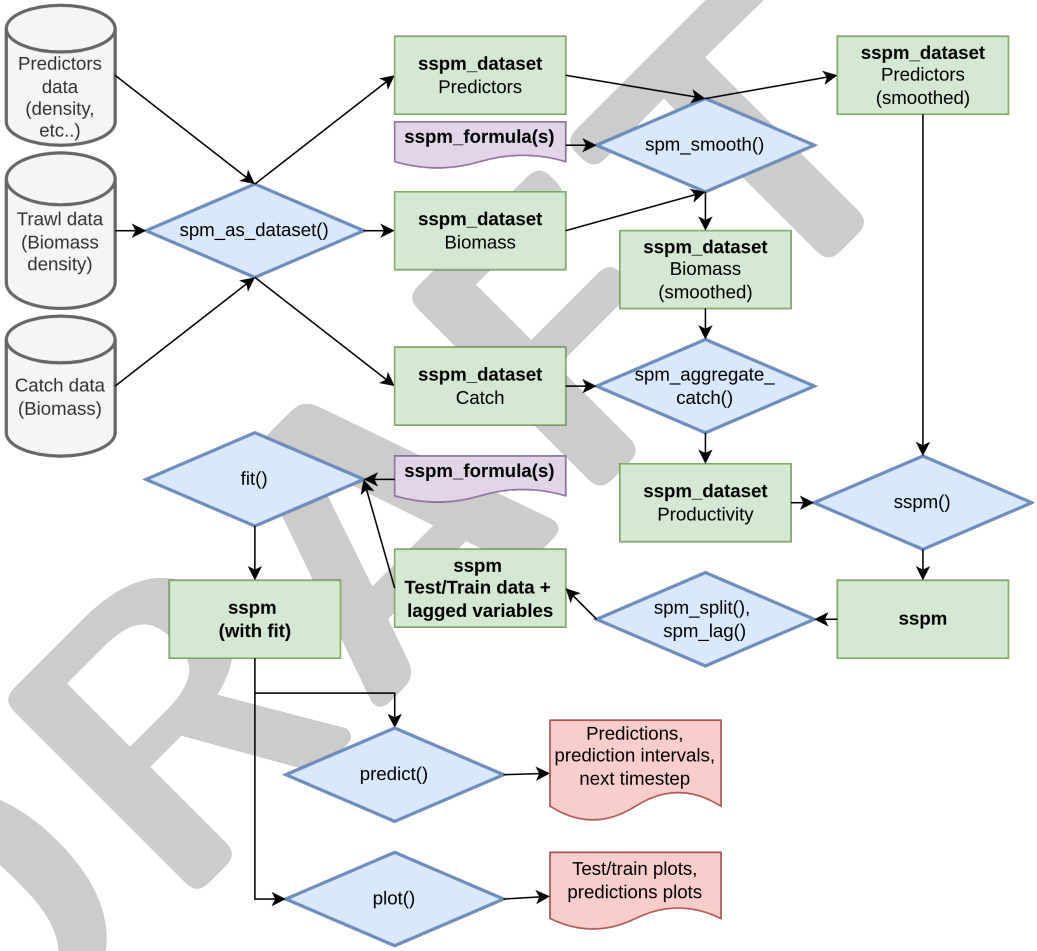
Rho => varying prod => covariance matrix => precision => basis functions and Gams

Results

The GAM biomass estimates are consistent with those of the current tool in use for the assessment of the stock, Ogmap, and provide valuable insights about the drivers of the rapid increase and decline of shrimp in the southern end of the shelf. Our approach demonstrates the model's ability to become a useful tool for modelling spatially-structured populations like fisheries stocks. The sspm package successfully modularizes each step of the modelling process and implements a range of useful features for modeling spatially-structured populations: spatial discretization, simplified GAM syntax, prediction intervals and scenario based forecasts for

longer-term trends. In a fisheries context, It illustrates how our model can be easily used by managers to forecast fisheries productivity under different management regimes. The package is also a tool to think about design choices when conceiving a user interface for managers and on best practices when it comes to adapting research code into management tools. Finally, our approach demonstrates how open source software tools can improve the accessibility and reliability of models for fisheries management.

Package design



Application to simulated data

Citations

Citations to entries in paper.bib should be in rMarkdown format.

If you want to cite a software repository URL (e.g. something on GitHub without a preferred citation) then you can do it with the example BibTeX entry below for Smith et al. (2020).

For a quick reference, the following citation commands can be used: - `@author:2001` -> "Author et al. (2001)" - `[@author:2001]` -> "(Author et al., 2001)" - `[@author1:2001; @author2:2001]` -> "(Author1 et al., 2001; Author2 et al., 2002)"

Figures

Acknowledgements

TBD

References

Smith, A. M., Thaney, K., & Hahnel, M. (2020). Fidgit: An ungodly union of GitHub and figshare. In *GitHub repository*. GitHub. https://github.com/arfon/fidgit